# INVESTIGATION OF PERFORMANCE ANALYSIS OF THERMO ELECTRIC GENERATOR AND ITS APPLICATIONS

**A SYNOPSIS**

*Submitted by*

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## 1.Introduction

The TEG system is a promising power generation technology and is the theme of abundant research in modern years. The literature review will focus on the schematic diagrams of the thermoelectric module, the different model of a thermoelectric generator, the price of numerous thermoelectric resources established on the raw substantial prices of the fundamental elements, applications of TEGs in existing systems like on-board aircraft generators system, cookstove, heat pipe, solar heat pipe flat, heat transfer mechanism ,low power application like inverter fed, supplying LVDC loads and Seebeck effect for the thermoelectric module, existing models of TEGs & Coil Gun, mathematical optimization methods and mathematical modeling of TEG system. The review will analyze the various aspects of the TEG system and its associated elements in order to provide a comprehensive overview of the technology. A discussion of the existing literature and a comparison between the various models will be included. The aim of this chapter is to provide a comprehensive description of the TEG system, its associated elements, models, and applications in demand to assess the present state of the technology and identify potential areas for further research.

The most important and practical method for utilizing thermal energy is internal combustion engines (IC engines), but due to their efficiency of only about 40%, the remaining thermal energies are lost as a heating loss. Vehicle industry in India has experienced the quickest growth during the last few decades. India generated 29 million automobiles in 2018 alone. By 2028, there are expected to be 404 million vehicles in India, up from 22 million in 2017. By performing any action, the human body produces a considerable amount of biological power which can be captured using a compact solar collector. Little machinery, such as the coil guns used by soldiers, can be powered by this energy.

However, when TEGs are used to supply non-linear loads, such as electronic devices with switching power supplies, there are some important considerations to take into account.

Non-linear loads draw current in a non-sinusoidal manner, which can cause distortion in the electrical waveform. This can lead to power quality issues, such as

harmonic distortion and voltage fluctuations, which can affect the performance of sensitive electronic equipment. Therefore, it is important to ensure that the TEG system is designed to provide clean and stable power to the non-linear loads.

One way to achieve this is by using a power conditioning system, such as an inverter or a DC-DC converter, which can convert the output of the TEG into a form that is suitable for the non-linear loads. The power conditioning system can also include filters and other components to reduce harmonic distortion and improve power quality.

A grid-connected thermoelectric generator (TEG) with maximum power point tracking (MPPT) is a system that uses TEGs to generate electricity and connects to the grid to supply power to the electrical grid. The MPPT function is used to optimize the power output of the TEGs by tracking the maximum power point (MPP) of the TEGs. This allows the TEGs to operate at their peak efficiency and generate more power.

A thermoelectric generator (TEG) fed low voltage direct current (LVDC) system with non-linear loads can experience power quality issues, such as harmonic distortion and voltage fluctuations. The TEGs generate DC power, which is suitable for LVDC systems, but non-linear loads can draw current in a non-sinusoidal manner, causing distortion in the electrical waveform.

Overall, a TEG-fed LVDC system with non-linear loads can be a viable solution for generating electricity from waste heat sources. However, careful consideration should be given to power quality issues, sizing, voltage regulation, MPPT control, and energy storage to ensure stable and reliable power supply to non-linear loads.

The usage of gunpowder in conventional rifles, which restricts the usage of the weapon to a specific purpose and rapidly deprives the ammo stock, has drawn the interest of scientists recently. When using a coil gun, the drawbacks of a conventional gun can be somewhat mitigated. It is quite difficult to transmit electricity using wireless technology and to monitor using IOT-based devices. In addition, the installation price is relatively expensive when compared to the standard methods. Boiler-based waste steam is used in real-time to generate power via TEG, and the system's conversion stages are quite intricate.

## 2. Literature Review

An overview of the recent developments in thermoelectric generators, including materials, structures, and performance. It discusses the advantages and challenges of

different materials used in thermoelectric generators, such as bismuth telluride and lead chalcogenides, and highlights the importance of optimizing the thermoelectric device structure to improve its performance, Chhatrasal et al.[1]

The high thermoelectric performance of nanostructured bismuth antimony telluride bulk alloys, which have a high figure of merit (ZT) of 1.4 at room temperature. It demonstrates the potential of nanostructured materials for improving the efficiency of thermoelectric generators, X. Shi,L et al.[2]

TEG arrays to supply power to non-linear loads. TEG array with a parallel-series configuration to supply power to a non-linear load. TEGs have progressively reached the public awareness and are used in the sectors of wearable gadgets, medical devices, wireless sensor networks, and architecture. Of course, beyond the applications of thermoelectric materials, Wissam Bou Nader et al.[3]

In a setting of energy conservation, thermoelectric generators (TEG) gadgets are becoming increasingly appealing aimed at energy production products. The development of improved thermo-generator tools with properties like high power competence, higher shelf life, cheap price, and simple assembly is required to meet tomorrow's difficulties.

Uses for these thermoelectric devices include space applications using radioisotope thermoelectric generators (RTG), discharge excess heat recovery systems attached to automobile exhaust pipes, and portable energy resources driven by human body heat. Its usefulness is also especially intriguing in an industrialized setting where a large portion of the energy utilized by plants is frequently lost as heat, G. Delaizir, et al. [4] .The Seebeck effect enables thermoelectric substances to transform thermal power into electric power, and vice versa (Peltier effects). Mechanical energy can be generated thanks to the thermoacoustic generator. This energy is related to the creation of a tension wave that causes fluctuations in the velocity of a compressible fluid. There are numerous techniques to convert mechanical energy into electrical.

A thermo-photo-voltaic producer's primary usage are dispersed coupled heat and energy production, however, research has already examined its potential in the automobile industry in the case of hybrid vehicles, the glass industry, and other high-temperature industries [2]. In order to meet electricity and heat demand and reduce emissions, poly-generation smart grids are being developed. These grids produce electrical energy,

warming, and chilling thermal power adjacent to end users, eliminating the major drawbacks of the compacted production method related to power communication. C. Ferrari et al , a Baltic German Physicist, Thomas Johann Seebeck observed that a closed loop made of two distinct metals connected in two places would divert a compass needle when there was a thermal gradient between the junctions, an effect that converts thermal difference directly into electricity, C. Ferrari et al.[5]

According to Figure 2.1 the TEG constitutes a variety of p-type and n-type TE matters that are attached to two substrates. Thermal connections between these materials are parallel, despite the fact that they are electrically united in a series to the configuration of a string of the p-n junction. Soldering clasps, the TE substances with the substrates. The interior face activity of TE material and binding linkages was the subject of numerous research. TEGs frequently use Sn-based (free of lead) solders for binding, M. Rivarolo et al. [6].

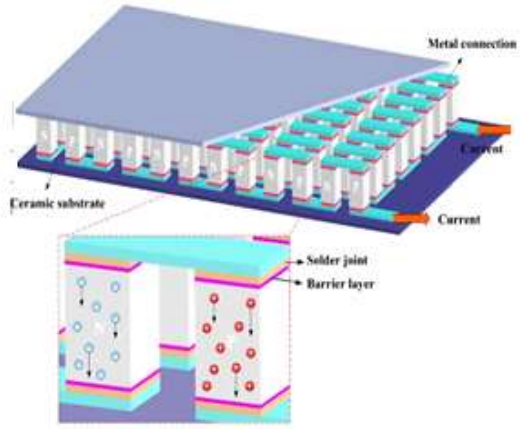



**Figure. 2.1**. Representation of the thermoelectric module [6]

Understanding the effect of enclosing stress on the setup's convective heat transfer coefficient (h) is the initial goal of the current investigation, B. Nishanth et al [7] ,L.L. Liao et al. [8]. The number of annual publications in thermoelectric technology rose from 500 to a peak of 2000 over the past 15 years, as reported by the Web of Science database. According to information from the Web of Science, Figure 2.1 displays the scientific literature on Thermo Electric Generators and Coolers.

The quantity of heat delivered to the TE materials varies on how well heat is exchanged among the TE device and the heat source, largely past the heat exchanger.

Figure. 2.2 shows the effectiveness of three combustible applications' projected TE waste heat recovery systems to that of TEG systems at the system level, K.Y. Sudharshan et al. [9].

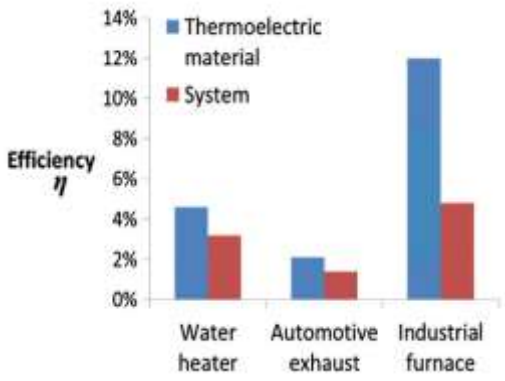



**Figure. 2.2**. Comparison of the Thermoelectric material efficiency to the generator system efficiency replicated for three potential purposes [9].

In [4], they describe how to quickly construct a versatile thermos generator for scenarios that need use at or near ambient temperature. The Spark Plasma Sintering (SPS), widely identified as Pulsed Electric Current Sintering (PCES) technology, is used to sinter (Bi, Sb) 2 (Te, Se)3 nano-powder and incorporate them in shielding matrices within a matter of 10 minutes.

The most important element influencing how much hot air is generated by exhaust gases. Heat recuperators that warm the combustion air or incoming gases before the ignition are being used to enhance it. Radiance conversion efficiencies of over 70% have been attained using this technique [5]. When more units are put on the micro-combustor systems than two or one modules, the total conversion efficiency of the micropower generator has been seen to rise. One module configurations were successful in achieving an overall conversion efficiency of 1.2%, two module configurations 2.56%, and four module configurations 4.6%, S. Uhl, M. Pellet et al. [10]. The behavior of the Thermo-Acousto-Electric Generator (TAEG) is disturbed by the active management of sound. The two major findings of these experimentations are the effectiveness and temperature gradient benefits of using this technique, as well as the occurrence of a hysteretic behavior that results in a difference between the onset temperature and the offset temperature, which is brought on by the feedback loop itself, S. LeBlanc et al. [11].

It then burned in this chamber to reach the desired temperature. When compared to the entrance air/fuel stream, the flue gas from the combustion chambers goes past the hot channel in the opposite current, S. Yadav et al. [12].

The steam generator must be designed over fatigue depending on the functioning of the power plants, and this examination is essential for obtaining the thermo-mechanical variable required. In order to operate below the ultimate load limit, the suggested approach evaluates the strain values on the crucial heat exchanger elements, like the tube sheet and tube sheet junction, G. Poignand et al.[13]. To introduce and present two different configurations for direct hybrid systems of gas turbine and fuel cell and to analyze these two structures based on their thermodynamic and thermo-economic models.

This research investigates the potential of using a thermoelectric generator (TEG) to power a coil gun battery using body heat. Coil guns are an innovative technology that allows for the use of reusable and multipurpose rounds in a firearm instead of traditional gunpowder. It also examines the ANSYS model of the TEG and its application in the development of autonomous, flexible wearable technologies and other applications such as the Internet of Things (IoT), military purposes, industrial services, consumer products, and non-consumer areas. Ultimately, this research provides insight into the potential to use body heat to power specialized applications such as medical ones, as well as renewable energy sources with uses ranging from mW to W power.

## 3. Research Problem

Among the most often key challenges as per the literature study:

a. Limited research on the performance of TEGs when they are connected to LVDC loads
b. TEGs fed LVDC particularly relevant for applications such as off-grid power systems where LVDC loads are commonly used
c Performance of TEGs using H-bridge converter
d. The coil guns for the military purpose were not investigated. And there is no analysis and investigation regarding the use of electrical energy garnered from a Bio-thermal energy harvester to allow multipurpose bullets to be used in a rifle
e Lack of investigations in the potential of thermoelectric energy harvesting as an energy source for flexible gadgets.

f. Efficiency becomes lower when analyzed with thermoelectric generators as a renewable energy source.

**4.. Objectives**

To research the idea and implementation of coil guns for military applications.

i To develop mathematical, ANSYS & Neural network models of Thermo Electric Generator.

ii Compare the performance of three different models of thermoelectric generators.

iii To improve the performance of thermoelectric generators using H-bridge inverter.

iv To analyse thermoelectric generators supplying nonlinear loads

v Performance analysis of Neural network Modelled Grid connected Thermo Electric Generator with MPPT.

vi To study the use of a Thermoelectric Generator (TEG) to generate energy from the human body and use it to charge a coil gun battery.

**5. Thermoelectric generators**

Thermoelectric generators are converting thermal energy into electric energy. The electrical voltage is generated between two ends of two different materials they connected together maintaining at different temperature

Voltage developed:

$$\Delta V = \alpha_s \Delta T \ldots\ldots\ldots\

$$R = R_L = \frac{V_L^2}{W_L} \ldots\ldots\ldots\

The n-type portion having

- Thermal conductivity of $1.607x10^{5}$W/m/K
- Isotropic resistivity of $8.33x10^{-4}\Omega$m
- Seebeck coefficient of $-150 \times 10^{-6}$ $VK^{-1}$

Result shown that temperature variation in hot and cold surface of ANSYS modeled TEG in Figure 7.1

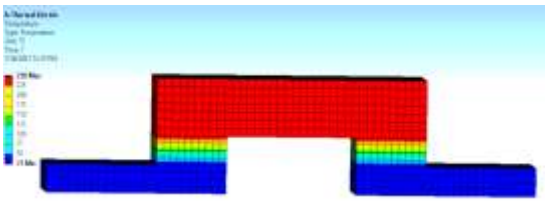


**Figure7.1** Temperature variation in ANSYS model

## 8. Neural Network Model of TEG:

One possible neural network architecture for modeling a TEG could be a multilayer perceptron (MLP) with two inputs, one for the hot side temperature and one for the cold side temperature, and one output representing the electrical power generated. The number of hidden layers and neurons in each layer can be determined through experimentation and optimization.

### 8.1 Data set

This data set is obtained by conducting practical experiment in SP1848 27145 SA TEG

**Table 8.1**. Test data of SP1848 27145 SA TEG

| S.No | $T_C(^0C)$ | $T_H(^0C)$ | $\Delta T(^0C)$ | V(Volt) | I(mA) | P(mW) |
|---|---|---|---|---|---|---|
| 1 | 25.39 | 27.8 | 2.41 | 0.039 | 0.412 | 0.016068 |
| 2 | 25.39 | 27.8 | 2.41 | 0.019 | 0.183 | 0.003477 |
| 3 | 25.39 | 28.7 | 3.31 | 0.035 | 0.344 | 0.01204 |
| 4 | 25.39 | 29.27 | 3.88 | 0.048 | 0.482 | 0.023136 |
| 5 | 25.39 | 29.7 | 4.31 | 0.093 | 0.921 | 0.085653 |
| 6 | 25.39 | 30.27 | 4.88 | 0.111 | 1.131 | 0.125541 |
| 7 | 11.89 | 31.4 | 19.51 | 0.02 | 0.161 | 0.00322 |
| 8 | 11.89 | 31.6 | 19.71 | 0.193 | 1.445 | 0.278885 |
| 9 | 11.89 | 31.11 | 19.22 | 0.085 | 0.84 | 0.0714 |

### 8.2. Developed NN model from data set

The Figure 8.2.1 NN model of SP1848 27145 SA TEG developed from the data obtained from experiment Table 8.1

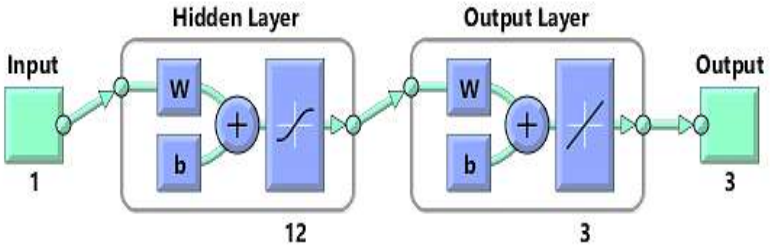



**Figure 8.2.1**. NN model of SP1848 27145 SA TEG

In comparison to the classification work, the regression task generates continuous data within a specified range.

Many such measures utilized to evaluate the prediction results are as follows:

a). Mean Squared Error (MSE)

b). Root-Mean-Squared-Error (RMSE).

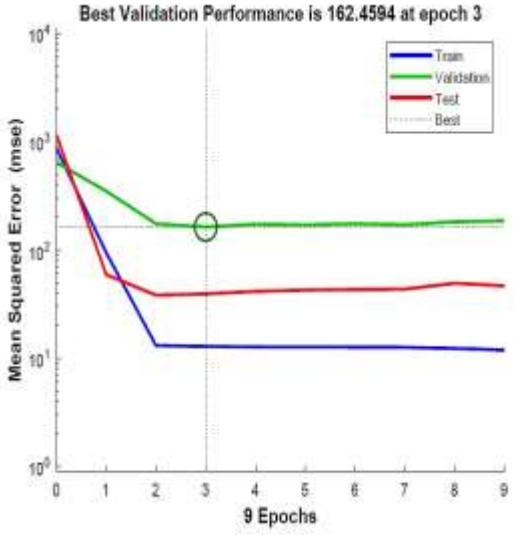
c). Mean-Absolute-Error (MAE).

d). $R^2$ or Coefficient of Determination.

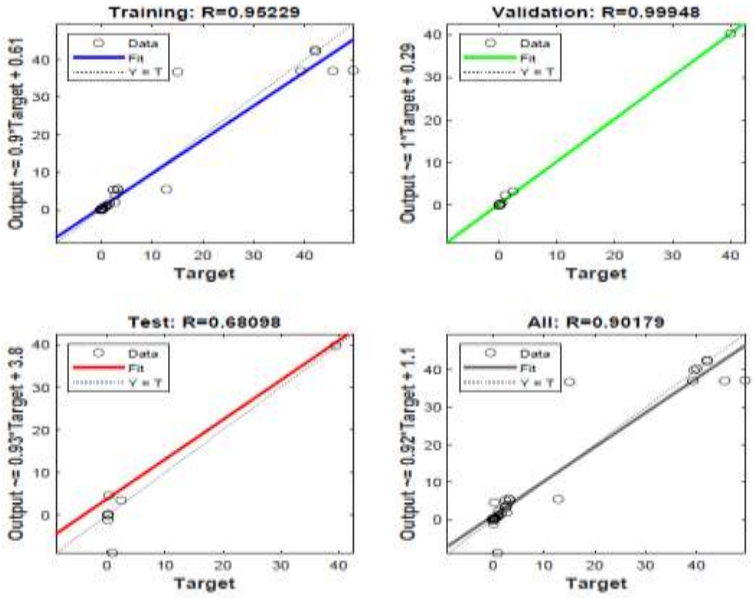
e). Adjusted $R^2$

### 8.3 Analysis of NN Model

The NN model result obtained shown in Figures 8.3.1 & 8.3.2




(a)




(b)

**Figure 8.3.1**. (a).MSE & (b).Regression graph of NN Model

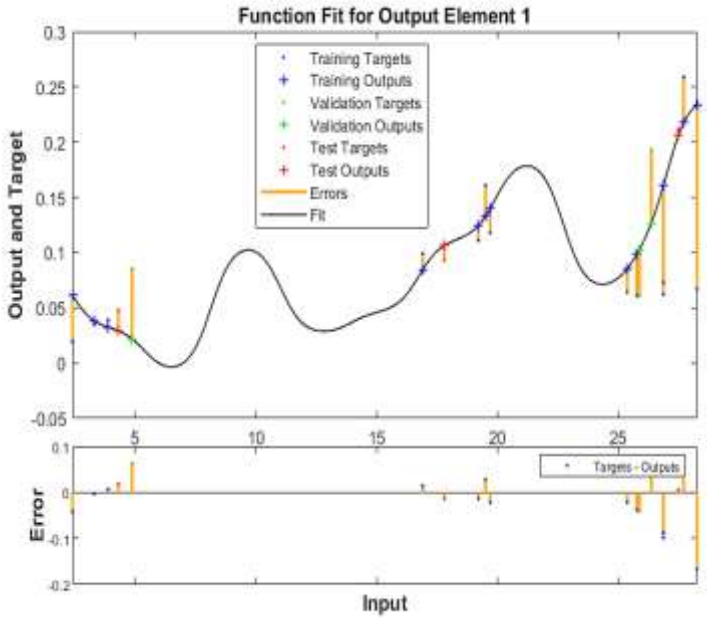



**Figure 8.3.2**. Fit function curve of NN Model

## 9. Low power Applications of TEG

TEGs are thermoelectric generators that can transform waste heat into electrical energy. Because of their ability to generate electricity from small temperature variations, they have been used in a variety of low-power applications.

### 9.1. Performance of Modified H- bridge inverter

A modified H bridge inverter is a type of inverter that is used to convert DC voltage to AC voltage. It is based on the H bridge circuit, but it has additional circuitry to improve the efficiency of the inverter**.**

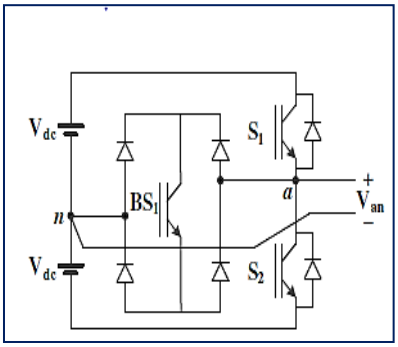



**Figure 9.1.1**. Modified H bridge inverter[3]

$V_{out}$= $V_{dc}$ * Duty cycle, Output current =$\frac{V_{out}}{R_{load}}$ ... ... ... ... ... ... ... ... ... ... ... (9.1)

Load type: Resistive Power requirement: 60W, Calculate the value of $Rl_{oad}$ using the formula:

$$R_{load} = \frac{V_{out}{}^2}{P_{load}} \text{ ..... (9.2)}$$

$$R_{load} = \frac{3^2}{60}$$

$R_{load} = 0.15\Omega$ select 1 Ω as load resistance

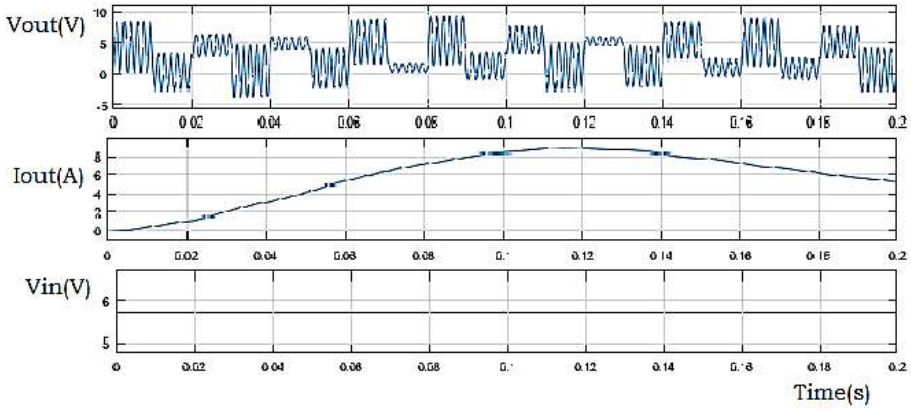



**Figure 9.1.2**. Output performance curve of Modified H bridge inverter

The performance of TEG using modified H bridge inverter obtained from mathlab simulation shown in Figure 9.1.2.

## 10. Thermo Electric Generator fed LVDC System analyzed with non-Linear Loads

A low voltage direct current (LVDC) system is a type of electrical power distribution system that transmits and distributes electricity using low voltage direct current. Non-linear loads are devices that do not draw current linearly in relation to the applied voltage and can create harmonic distortion and other power quality problems in electrical systems.

There are various aspects to consider when studying an LVDC system supplied by a TEG with non-linear loads. For starters, the TEG's output voltage and current may not be consistent because they vary with temperature and load. This can make designing a stable and reliable LVDC system difficult. Furthermore, non-linear loads can cause harmonics in the system, which can cause voltage distortion. The Figure 10.1 shows the performance of TEG supplying a non linear load

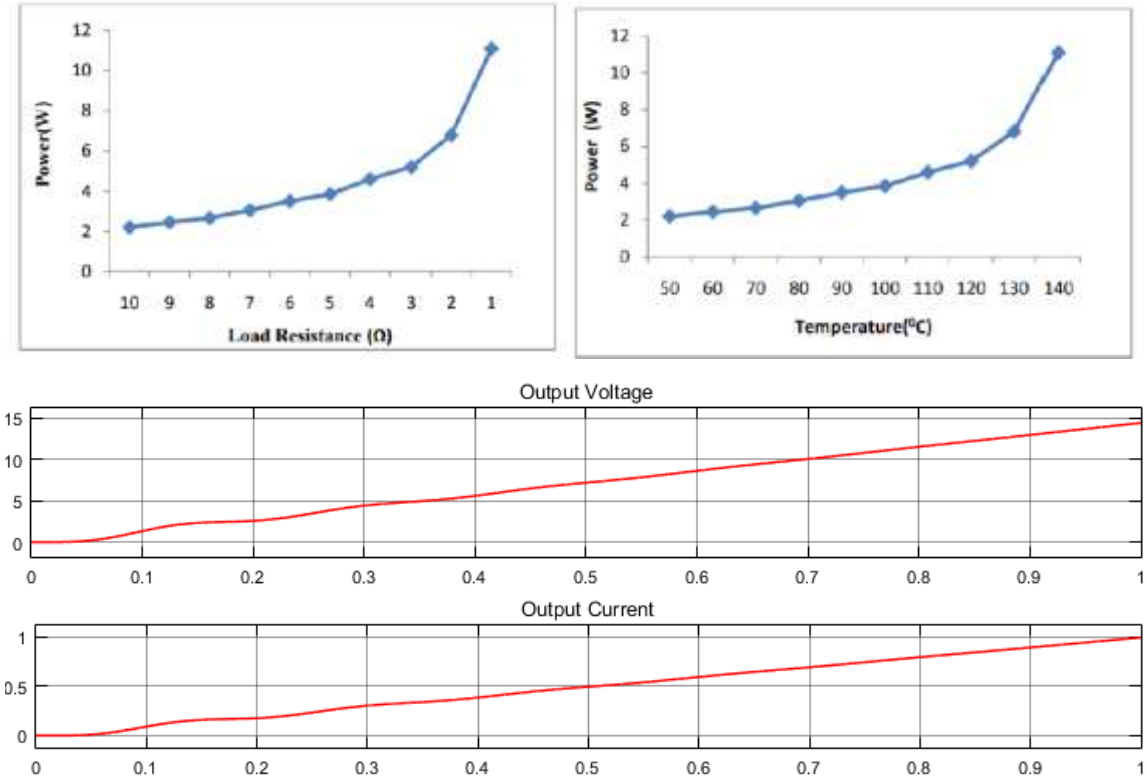



**Figure 10.1.** Thermo Electric Generator fed LVDC System analyzed with non Linear Loads

## 11.Defense application of TEG

### 11.1 Introduction

TEGs have various potential defense applications, particularly in remote or harsh areas where access to standard power sources is limited or unavailable. TEGs' possible defense uses include the following.

Remote sensor power: TEGs can be used to power remote sensors and monitoring systems in places where power is scarce. This is especially beneficial in military and defense applications where situational awareness is essential.

Power communication systems: such as radios and satellite phones in distant or inhospitable settings. This is especially crucial in military operations where communication is critical. TEGs can be placed into personal equipment, such as backpacks or uniforms, to supply power for electronic devices like radios or GPS systems. TEGs can be used to provide electricity to field hospitals in distant or disaster-stricken places where access to regular power sources may be limited or unavailable.

In addition to the above application TEGs can also used as a source of coil gun.

### 11.2. Single stage Coil gun

A Gauss rifle, also known as a coil gun, is a form of mass driver that uses one or more coils as electromagnets in a linear motion to accelerate a ferromagnetic or conductive projectile to a high velocity. The speeding projectile travels along the centre axis of one or more coils strung around a barrel in a coil gun The coils are turned on and off in a specific sequence, enabling the projectile to speed rapidly along the barrel due to magnetic forces.The operation of TEG powered coil gun block diagram shown in Figure 11.2.1

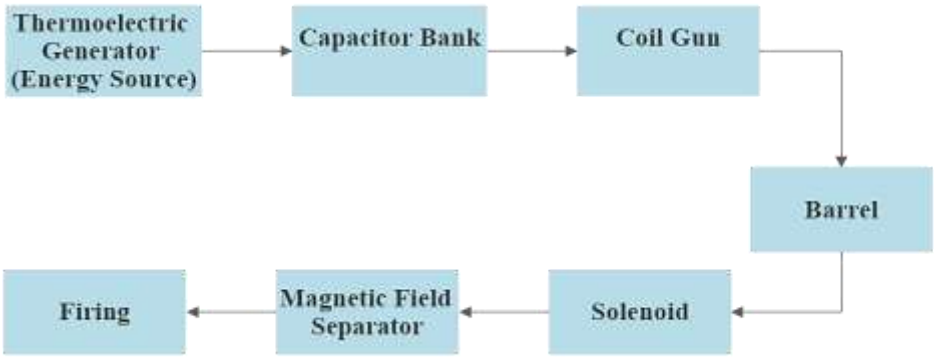



**Figure 11.2.1**. Single stage coil gun

The coil gun is made up of an energy source, a capacitor bank, a coil gun, a barrel, a solenoid, and a magnetic field separator

While the bullet is being pushed by the magnetic force created by the coil, due to eddy current formed.The energy source is a lithium-ion battery. It's a rechargeable battery and are widely used in various electronic gadgets and their employment in military and aerospace applications

A thermoelectric generator, a capacitor bank, a non-ferromagnetic barrel, a solenoid (multi-layered coil), a relay, and an Arduino Nano (ATmega328P microcontroller) of high performance and low power are all mounted on the thigh to absorb heat from the human body and convert it into voltage and current.

The lithium-ion battery specifications are model no. ISR18650-10C, Nominal Voltage of 3.7V, Charge Voltage of 4.2V, Current Capacity 2000 mAh, Max. Continuous Discharge Current of 30A

The number of layer and outer diameter of solenoid increases, it will increase the distance of projectile travelled. Graphical representation shown in Figure 11.2.2

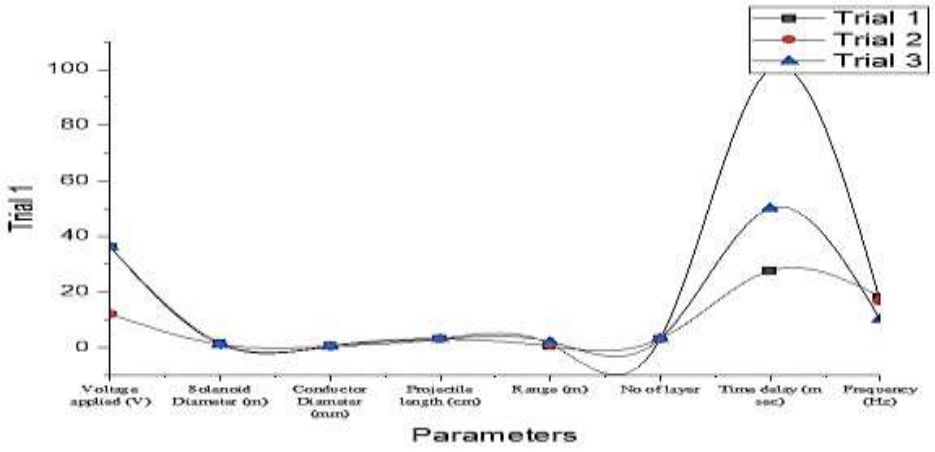



**Figure 11.2.2** Performance of different layers and outer diameter of solenoid for projectile motion

## 12.Conclusion

Mathematical model of thermoelectric generators typically solving a system of differential equations to predict the temperature and voltage outputs. Neural network models can be trained using data from experiments or simulations to predict the performance of thermo-electric generators. ANSYS is a good choice for detailed simulations and design optimization. Highlighted the performance of a coil gun propulsion using a relay and a

manual switch to generate energy. It was found that the power and voltage was directly proportional to current.It is found that the maximum hot side temperature of the SP1848 27145 SA TEG is $50^0$C and the minimum temperature is $27^0$C, and the Seebeck coefficient, voltage, current, and Figure of Merit performances are also plotted. This research shows that thermoelectric energy harvesting can be utilized to supply specialized applications such as medical ones, and that thermoelectric generators can be used as independent renewable energy sources.

**13.Research Findings**

Thermoelectric generators (TEGs) are devices that use the Seebeck effect to transform heat energy into electrical energy. TEG efficiency has been the subject of recent study, with the goal of deploying them in a number of applications, including waste heat recovery and power generation.

i. Several study findings have been made in the mathematical modeling of TEGs. One work published in the Journal of Electronic Materials offered a mathematical model for TEGs that takes the temperature distribution along the device as well as the non-linear features of the thermoelectric materials utilized into account. The model properly predicted the TEG's electrical power production under various operating situations.

ii Another area of study has been on modeling the performance of TEGs using ANSYS, a finite element analysis software. In one work published in the International Journal of Heat and Mass Transfer, the thermal and electrical behavior of a bismuth telluride TEG was simulated using ANSYS. The results demonstrated that the model effectively predicted the TEG's temperature distribution and electrical power production.

iii TEGs have also been modeled using neural networks (NN). A neural network model was employed in one study published in the Journal of Power Sources to forecast the electrical power output of a TEG. The model was trained using experimental data and was able to predict the performance of the TEG under various operating situations.

iv The study discovered that using H-bridge inverters enhanced TEG efficiency, especially

at modest temperature differentials. The use of H-bridge inverters can increase the performance and efficiency of TEGs, particularly when temperature differentials are small and loads are large. However, the inverter's design and control parameters are crucial in determining the performance of the TEG with the inverter.

v TEGs can supply non-linear loads, although their performance is affected by the load characteristics and the TEG's working conditions. The employment of voltage regulators and PWM approaches can increase the stability of the TEG's voltage and current waveforms, which in turn improves the device's power output and efficiency.

vi The researchers employed a TEG device to harvest energy from the temperature difference between the skin and the ambient air, and discovered that up to 5.5 milliwatts of power may be generated during exercise.The need for the device to be in close contact with the skin, as well as the relatively modest power output, are significant practical hurdles to employing TEGs to harvest energy from the human body. TEGs, on the other hand, are an intriguing technology with numerous possibilities in energy harvesting.

**14.Organization of the thesis**

In the further chapters, we walk through our research process, modeling, and simulations of the work and subsequently interpret the results of our proposed model.

**Chapter 1:** All three models are valuable for designing and optimizing TEGs for specific applications, and they can assist engineers in improving TEG efficiency and dependability.

**Chapter 2 :**TEGs' performance can be improved by using an H-bridge inverter, which converts their DC voltage output into AC voltage that can be utilized to power electrical loads. The power output of the TEG can be enhanced by improving the inverter's efficiency and load resistance.

**Chapter 3:** When a TEG is used to power non-linear loads like motors or power electronics, the output voltage and current might get distorted due to the load's non-linear characteristics.

**Chapter 4:** It may be possible to develop a self-sustaining system that derives electrical energy from the human body and uses it to power a coil gun using TEG and a coil gun battery. However, it is crucial to note that TEGs have a relatively poor efficiency, which

implies that a big amount of body heat may be required to generate a significant amount of electrical energy.

**Chapter 5:** Discloses the results and elaborates the findings of our work.

**Chapter 6:** Conclusion of all work

**Chapter 7:** The future scope

**Reference**


1. Chhatrasal Gayner , Kamal K. Kar, Recent advances in thermoelectric materials, Progress in Materials Science, **83**(2016), 330-382.
2. X. Shi,L. Chen &C. Uher , Recent advances in high-performance bulk thermoelectric materials. Pages 379-415
3. Wissam Bou Nader , Joy Chamoun , Clément Dumand , Thermoacoustic engine as waste heat recovery system on extended range hybrid electric vehicles. Energy Conversion and Management, **215**(2020), 112912
4. G. Delaizir, J. Monnier, M. Soulier, R. Grodzki, B. Villeroy, J. Testard, J. Simon, C. Navone, C. Godart, A new generation of high performance large-scale and flexible thermo-generators based on (Bi,Sb) 2 (Te,Se) 3 nano-powders using the Spark Plasma Sintering technique, Sensors Actuators, A Phys. **174** (2012) 115–122.
5. C. Ferrari, F. Melino, M. Bosi, The critical role of emitter size in thermo-photovoltaic generators, Sol. Energy Mater. Sol. Cells. **113** (2013) 20–25.
6. M. Rivarolo, A. Greco, A.F. Massardo, Thermo-economic optimization of the impact of renewable generators on poly-generation smart-grids including hot thermal storage, Energy Convers. Manag. **65** (2013) 75–83.
7. B. Nishanth, D. Sanjeev Kumar, A. Naveen, R. Vijayanandh, M. Senthil Kumar, Energy harvesting from a Gas Turbine Engines exhaust heat Using Quantum Well Thermo Electric materials Generator (QWTEG), Mater. Today Proc. **4** (2017) 8378– 8386.
8. L.L. Liao, M.J. Dai, C.K. Liu, K.N. Chiang, Thermo-electric finite element analysis and characteristic of thermoelectric generator with intermetallic compound, Microelectron. Eng. **120** (2014) 194–199.
9. K.Y. Sudharshan, V.P. Kumar, H.C. Barshilia, Performance evaluation of a thermally concentrated solar thermo-electric generator without optical concentration, Sol. Energy Mater. Sol. Cells. **157** (2016) 93–100.

10. Uhl, M. Pellet, J. Tschanz, E. Laux, T. Journot, L. Jeandupeux, H. Keppner, abrication of Highly-integrated Thermoelectric Generators Based on Ionic Liquids, Iater. Today Proc. **2** (2015) 669–674.
11. .LeBlanc, Thermoelectric generators: Linking material properties and systems ngineering for waste heat recovery applications, Sustain. Mater. Technol. **1** (2014) 6– 35
12. Yadav, P. Yamasani, S. Kumar, Experimental studies on a micro power generator sing thermo-electric modules mounted on a micro-combustor, Energy Convers. Ianag. **99** (2015) 1–7
13. Poignand, C. Olivier, G. Penelet, P. Lotton, Hysteretic behavior induced by an ectroacoustic feedback loop in a thermo-acousto-electric generator, Appl. Acoust. **05** (2016) 110–115.
14. .Bensaid, M. Brignone, A. Ziggiotti, S. Specchia, High efficiency Thermo-Electric ower generator, Int. J. Hydrogen Energy. **37** (2012) 1385–1398.
15. .A. González-Gómez, J. Gómez-Hernández, J. V. Briongos, D. Santana, Transient ermo-mechanical analysis of steam generators for solar tower plants, Appl. nergy.**212** (2018) 1051–1068.

**List of Publications**

1. **P. Sreekala,** Dr.A. Ramkumar, Dr.K. Rajesh Enhancing the defense application with ANSYS model of thermoelectric generation for coil gun *Sustainable Energy Technologies and Assessments*,ELSEVIER , Volume 54 , December 2022, 102806
2. **P. Sreekala,** Dr.A. Ramkumar, Dr.K. Rajesh Performance comparison and analysis of mathematical, ANSYS and neural network model of a thermo electrical generator *Measurement: Sensors* ELSEVIER , MEASEN 100675
3. **P. Sreekala,** Dr.A. Ramkumar, Dr.K. Rajesh Performance Analysis of Neural Network Modelled Grid Connected Thermo Electric Generator with MPPT , *IEEE*, 978-1-6654-2690-9/21/$31.00 © 2021 IEEE
4. **P. Sreekala,** Dr.A. Ramkumar, Dr.K. Rajesh Thermo Electric Generator fed LVDC System analyzed with non Linear Loads, *IEEE* , 19892614
5. **P. Sreekala,** Dr.A. Ramkumar, Dr.K. Rajesh Enhanced Performance of Thermoelectric Generator by Modified H-Bridge Converter , *IEEE*, 19265035